ON THE THRESHOLD OF OTHER WORLDS

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ON THE THRESHOLD OF OTHER WORLDS

L. Ksanformaliti, Eng.

A comparatively short time ago it seemed that there could be nothing in common between radio engineering and astronomy. However, in this day and age such a view is hopelessly antiquated. Now, at astronomical conferences, together with reports on investigations of stars and planets, there are reports on new electronic devices; not only are photographs of the other side of the moon discussed, but also the electronic equipment which transmitted them. Radio engineers now constitute a considerable portion of observatory personnel. It is clear that there is as much electronics as optics in the new large telescopes.

Here is one of the many examples. Figure 1 shows an automatic electronic polarimeter which has been developed at the Abastumani Astrophysical Observatory of the Academy of Sciences of the Georgian SSR. This apparatus is an electronic computer of nondiscrete operation. Measuring definite parameters of a beam of light, it solves several equations in which these parameters are contained and in 0.01 of a second computes the result. The circuit consists of 38 electron tubes and 35 diodes. Studies of the moon and planets, carried out at the observatory with the aid of this new device, made it possible to obtain valuable data concerning the composition and structure of their surfaces.

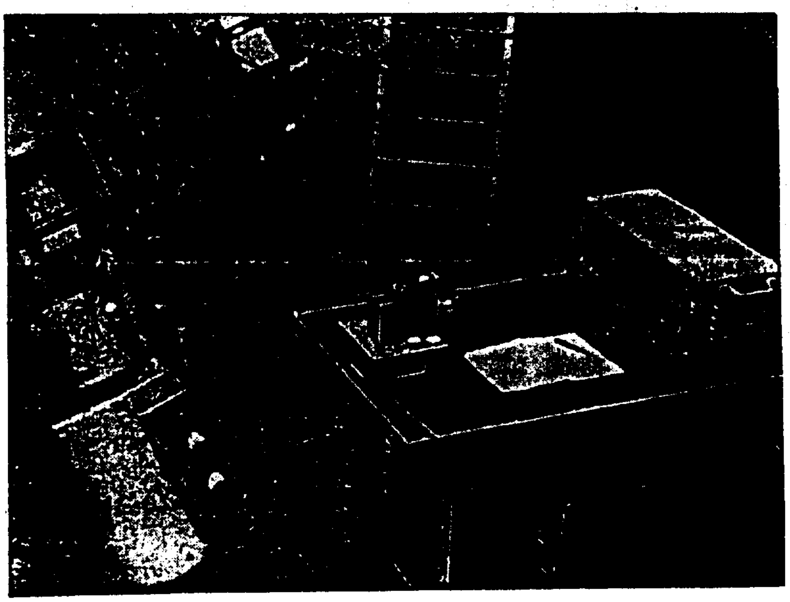

Fig. 1. Automatic electronic polarimeter. Hinged assembly attached to a 40-centimeter refractor.

Electronic devices and methods of using them in astronomy are extremely interesting and unusual.

It is known that the eye registers only a very small interval of wavelengths in the spectrum of electromagnetic oscillations from 4,200 to 7,000 angstroms, which corresponds to frequencies from 430 to 715 teracycles [millions of megacycles]. Within this range, optical astronomy is interested in the measurement of light fluxes (photometry), the distribution of radiant energy throughout the range (spectrometry), the determination of the plane in which the electrical oscillation vector lies and the determination of the corresponding quantitative correlations (polarimetry), and a number of other problems. All of them are solved by electronic methods.

It is understood that any electronic device must begin with a light-energy detector which responds to this energy by giving rise to a current, a voltage, or a change in resistance. These detectors are characterized, first of all, by the frequency range in which they must operate and by their sensitivity.

The most widespread form of detector used in astronomy is the photoelectric multiplier (PEM). It is a combination of an ordinary vacuum phototube and an electron multiplier.

Such a system may be more sensitive than the most acute sight, but it has its limits. First of all, the photocathode has a slight thermal emission. Amplified millions of times, it becomes appreciable, and therefore there is a current at the output of the PEM in the absence of light.

The other limit is imposed by the quantum structure of light. A flux of 1,000 quanta per second may be measured easily enough, but the uneven reception of quanta produces an additional Schottky effect.

Photoelectric multipliers are made with different types of cathodes, so as to permit their use in all parts of the spectrum except the far-infrared regions. PEM's are typically "single-channel" devices; they are not able to transmit the brightness distribution at points in the photocathode.

Figure 2 shows a schematic of an astronomical photometer. A perforated disk rotated by a synchronous motor modulates the light flux. Operating synchronously with the modulation is a phase-detector with a large time constant, which makes it possible to separate the signal from the noise even when the signal-to-noise ratio does not exceed 0.001. A special program device makes measurements, compares and then prints the result. This device has also been set up at the

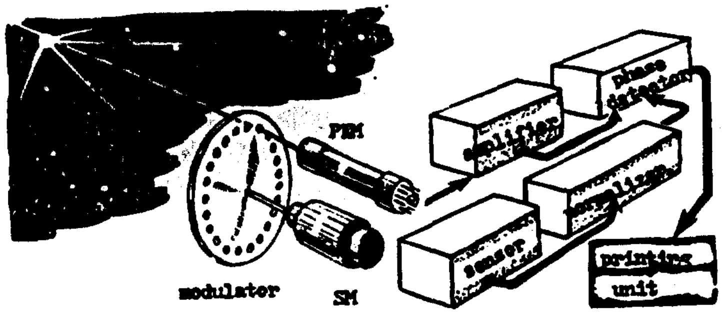

Fig. 2. Photometer used in astronomy (program device not shown).

Of great interest is the idea of a photoelectric device which would permit automatic tracking of a star by a telescope (photoguide). A PEM would serve as its detector. A photoguide has been developed at the Leningrad Institute of Electromechanics (Fig. 3).

The thermoelement and the bolometer are indispensable instruments in astronomy. They may be used within the range from visible light to submillimetric radio waves. No other devices have such a wide band.

The thermoelement is a miniature thermocouple usually housed in a vacuum. The junction of two heterogeneous wires is blackened in such a way that all of the radiation falling on it is absorbed and slightly warms the junction. A thermal emf appears, which may be measured with a high-sensitivity low-resistance galvanometer. Amplification of this emf by vacuum-tube circuits is different, since it is very small, and a low resistance cannot be used without a converter. The use of low-input-resistance transistor circuits is of great interest in this case; however, transistor noise introduces a complication.

The bolometer consists of two small metal plates with a thickness of fractions of microns, which are also blackened and enclosed in a vacuum. The light flux which is to be measured is directed toward one of them. Due to a change in the resistance of this plate, resulting from its being heated, an imbalance, which is proportional to the absorbed radiant energy, appears in an electrical bridge circuit. The bolometer is also inertial and its bridge has a low output resistance.

These devices which are used above all, as detectors of infrared light, are single-channel. It is true that recently a mosaic screen of light-sensitive semiconductor type (photoresistor), which is a multichannel device, was developed. The sensitivity of thermoelements and bolometers does not exceed 10^{-11} watts with a time constant of about 1 second.

The image-converter tube (ICT) is the only "multi-channel" device of its type, where an electron stream carries information about the entire image at once. A semitransparent photocathode is placed on the inner surface of the butt-end of the envelope, as in the case of the PEM. Naturally, the cathode, in this case too, determines the spectral purpose. An antimony-cesium cathode operates well in the green-violet and ultraviolet regions, a bismuth-cesium cathode covers the entire visible range, and an oxygen-silver-cesium cathode makes penetration into the near-infrared region possible. There are also other types of photocathodes.

Special electronic lenses, which are electric fields formed by special electrodes, direct the photoelectrons to the anode, as in the case of beam-focusing devices in kinescopes. This is done in such a way that the structure of the stream is not distorted, and the transmission of the image is accompanied only by a reduction of its size. The anode is a fluorescent screen, where it is possible to view or photograph the image. Image-converter tubes are used to increase the brightness of an image and, if necessary, to convert it from an invisible (e.g., infrared) to a visible form.

Perfection of these devices has led to multistage ICT's, where the brightness of the image is subsequently amplified. A brightness amplification of 60-120 times is practical for three-stage ICT's, while single-stage ICT's give an amplification of only 6 to 15 times. In other cases it has become possible to utilize more fully the light from the screen (anode). For this purpose, the thickness of the envelope is reduced in that area to tenths of millimeters and a photographic film is clamped down on it ("contact ICT" or "contact tube"). Designs were also developed where the photographic plate was located on the inside in place of the anode. However, in order to reach it, it was necessary to break the tube. Even when several plates, made interchangeable by a clever device, were used, this was too costly.

Very recently, television astronomical systems have come into use. In the Soviet Union the most significant work in this direction has been done by N. F. Kuprevich, a senior scientific worker at the Pulkovo Observatory, A device originated by him uses a method of accumulation, in which a faint image is projected onto the photocathode of an image orthicon for a long period of time in the absence of a scanning beam. This "builds up" a potential relief on the corresponding electrodes of the tube. Then a single-sweep scanner is turned on and an image with greatly amplified brightness on the televisor screen of a closed-circuit television system (the brightness is of the same order of magnitude as in the case of multistage ICT's) eliminates the problems associated with photography.

The television system is rather complicated to set up and operate, but it possesses great possibilities. Thus the minute details of images of astronomical objects on photographic plates always appear blurred.

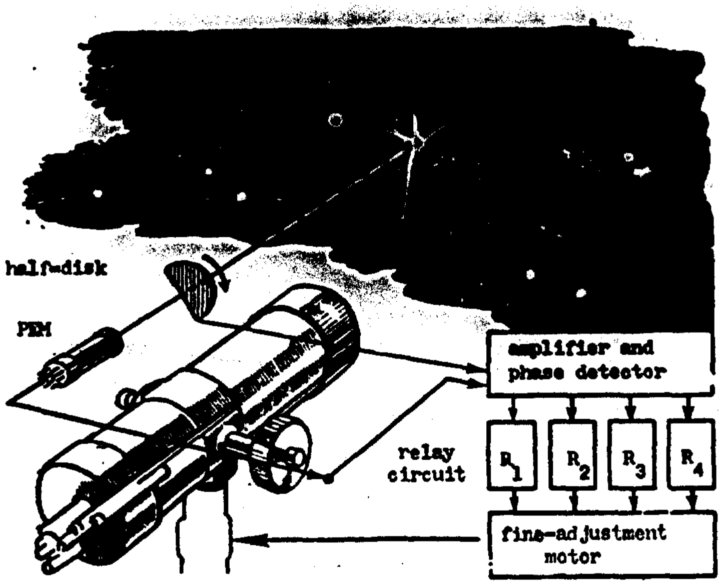

Fig. 3. Device for automatic of a star by a telescope (photoguide). During rotation of the half-disk, the current of the PEM will be invariable only if the beam of light passes exactly along its axis; otherwise, the current is modulated, thus causing the correcting motors to be switched on.

This is explained by the continuous jitter of the images. A similar phenomenon is known to everyone as the twinkling of stars. A television system, because of its brightness magnification, makes it possible to reduce the exposure period and consequently the "blurring" of the images. The television system is, in essence, single-channeled, but due to linear scanning it is capable of transmitting images, which puts it in the same class with ICT's. With regard to threshold of sensitivity, both of these devices are inferior to the PEM.

From all that has been mentioned, it is apparent that science has put very powerful technical means at the disposal of astronomers. It would seem that there is now no basis for dissatisfaction. However, this is not the case. It is known, for instance, that certain astronomical observations are now being made with satellites without the participation of men. The whole world has seen the photographs of the other side of the moon taken by the "electronic astronomer," the Soviet AMS, which was launched on October 4, 1959. It was obvious that in this case no other way was possible. It was also necessary to send an AMS to Venus, since the orbit of that planet is located within the orbit of the earth, and at times when it approaches the earth, it turns its dark, and therefore, invisible, side toward us.

Many important problems will someday be solved by sending astronomical equipment beyond the limits of the earth's atmosphere. Take Mars, our nearest neighbor, as an example. The enigma of Mars (its "canals" and other details) disturbs not only astronomers. The other luminaries also have many enigmas (even the moon has many). It would seem that it is only necessary to look into a high-powered telescope, and a great deal would become clear, but, in actuality, this is not the case. Instead of the clear contours of a planet, you see a sphere, trembling like the flame of a candle in the wind, a sphere with continuously floating hazy spots. This is the influence of the earth's atmosphere, where currents of air of different density produce a continuously varying refraction of light rays. Even when the atmosphere is very calm, it is still not possible to distinguish any of the small details. However, trembling and twinkling is but one side of the matter. The whole trouble lies in the fact that an overwhelming part of the electromagnetic spectrum does not reach the surface of the earth. Meanwhile, a study of precisely this part of the spectrum can give science, to no lesser degree than a blind man, the ability to see.

That is why the sending of observatories beyond the limits of the atmosphere (first on satellites, then into the moon) is now an urgent necessity.

It is also not difficult to understand that, using small telescopes, no matter what magnification they give, it is not possible to distinguish the small details of the planets. It is impossible because of the effect of the so-called diffraction limit. For instance, in order to distinguish details on the moon which measure 40 meters, a telescope with a diameter of no less than 65 cm is necessary. But large telescopes prove to be so heavy that they bend under their own weight. It is necessary to increase the rigidity of the construction, which in turn, increases the weight, and so on.

Is there a way out of this situation? Yes, there is. It is found in the fact that a large telescope placed on a satellite would weigh nothing. Its rigidity can be reduced to a minimum, and the mass of the structure will be small, so that putting it into orbit becomes inexpensive.

It is apparent that in the future it will be more expedient to set up telescopes on the moon, where they will weigh 1/6 of what they weigh on earth. It may be said without exaggeration that such an "outer observatory" equipped with electronic techniques and computer machines (they may be located on the Earth) will be able to solve, in a short time, hundreds of today's problems. It is interesting to note that a night on the moon is 29.5 times longer than on the Earth, as is a day also. Consequently, it is possible to conduct observations there both day and night. On the moon and in the cosmos there is the possibility of using new open electronic devices, for, you see, the vacuum there is such as has never been attained in any vacuum tube.

Finally, we cannot fail to mention yet another problem which is now passing from the pages of sicence fiction to the laboratory of the scientist. We are speaking of cosmic radio-emission of artificial origin. It would be important not only to receive i.. but also to decipher it. Despite the available predictions concerning the specific wavelengths where these signals should be searched for, it will be necessary to study the entire spectrum.

The progress of Soviet science and engineering, the historic flights of Soviet passenger space ships, and the great successes of our motherland in the conquest of cosmic space graphically attest to how successfully the ancient dreams of mankind and the plans which were considered utopian not long ago have been carried out by the Soviet Union. We are confident that in the near future Soviet astronomers will be able to travel to the moon, in order to make observations and to check their hypotheses.

Abastumani Astronomical
Observatory of the Academy
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